HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND
U S ARMY

ATLAS

OF

ARCTIC ENVIRONMENT

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

MARCH 1961

Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va. 22151

NATICK, MASSACHUSETTS

Reprinted January 1965

HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
QUARTERMASTER RESEARCH & ENGINEERING CENTER
NATICK, MASSACHUSETTS

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

RESEARCH STUDY REPORT

RER-33

ATLAS OF ARCTIC ENVIRONMENT

ANDREW D. HASTINGS, JR., M.S.
GEOGRAPHER
REGIONAL ENVIRONMENTS RESEARCH BRANCH

PREPARED FOR

GEOPHYSICS RESEARCH DIRECTORATE, AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
AIR FORCE RESEARCH DIVISION, AIR RESEARCH & DEVELOPMENT COMMAND
BEDFORD, MASSACHUSETTS

USAF PROJECT NO. 60-572
QMC PROJECT NO. 7X83-01-008

MARCH 1961

CONTENTS

ATLAS OF ARCTIC ENVIRONMENT

1. Introduction

This text provides supplementary information concerning sources and reliability of a series of twenty-two maps prepared at the request of the Geophysics Research Directorate, Air Force Cambridge Research Laboratories. The purpose of the study was to map the distributions of various climatic and terrain phenomena which might influence the selection of unprepared landing sites for wheeled aircraft in the Arctic. The study area includes all lands north of 65 degrees North Latitude. Despite the presence of dashed isopleths over ocean areas (included to give continuity to the lines), no reliable indication of landing conditions on sea ice is intended.

Major references used as sources of data in compiling the maps are listed in Section 4. Other source materials which were used to a lesser extent are to be found in the bibliographies contained in certain of these references. Entries containing such bibliographies are preceded by asterisks.

2. Discussion of maps

A. Major physiographic features (Map 1)

The Polar Stereographic projection on which all maps in the series were based was adapted from the Army Air Force Strategic Planning Map of the Northern Hemisphere (SP-5), published in January 1945. The hypsometric shading on this particular map is delimited by contours at sea level, 1,000 feet, 5,000 feet, 9,000 feet, and 13,000 feet. Areas above 13,000 feet elevation are confined to very small patches in the Alaska, Wrangell, and St. Elias Ranges of southern Alaska. Although unshaded, they are difficult to detect at this map scale. Names of physiographic provinces are essentially those of Lobeck (9) with minor modifications by the author.

B. Vegetation zones (Map 2)

The zones of natural growth shown on this map are based upon density and height rather than floristic composition. The map's usefulness lies in the suggestion of relative openness, surface visibility, and availability of materials for construction and fuel. Many of the lines represent transitions wherein two adjacent zones intermix rather gradually throughout belts of variable width.

One of the most significant lines on the map is the northern limit of Forest Tundra which represents the northern extent of tree growth in most areas. This was derived from Polunin (11), who based its position on a consensus of several authorities.

THE SMALL SCALE OF THE MAP AND MANY GAPS IN THE BASIC INFORMATION MADE IT NECESSARY TO GENERALIZE WITHIN ZONES. FOR EXAMPLES, THE TUNDRA ZONE DOES NOT SHOW THE CONSIDERABLE AREAS OF BARREN GROUND WITHIN IT, NOR DOES THE FOPEST ZONE REFLECT THE EXTENSIVE ECONOMIC DEFORESTATION WHICH IS COMMON IN SCANDINAVIA AND IN THE RUSSIAN LOWLANDS SOUTH OF THE 60TH PARALLEL. THE ZONATION FOR MUCH OF NORTH AMERICA WAS TAKEN FROM THE ATLAS OF CANADA (3) WHILE THE GREAT SOVIET ATLAS (17) PROVIDED THE PRINCIPAL AUTHORITY FOR EURASIA. VARIOUS OTHER GEOGRAPHICAL REFERENCE WORKS WERE CONSULTED.

c. STATION LOCATIONS AND POLITICAL DIVISIONS (MAP 3)

ALL STATIONS WERE LOCATED BY COORDINATES GIVEN IN THE MOST RECENTLY AVAILABLE GAZETTEERS BY THE U.S. BOARD ON GEOGRAPHIC NAMES. THERE ARE ABOUT 350 STATIONS SHOWN ON THIS MAP; HOWEVER, DATA FROM MORE THAN 900 STATIONS WERE UTILIZED ALTOGETHER. SPELLINGS OF NAMES ARE THOSE CURRENTLY RECOGNIZED BY THE BOARD ON GEOGRAPHIC NAMES, EXCEPT FOR CERTAIN SIMPLIFICATIONS THAT HAVE BEEN APPLIED TO THE TRANSLITERATION OF RUSSIAN NAMES AS RECOMMENDED BY SHABAD (14).

LOCATIONS SHOWN FOR SHIPS OR FLOATING ICE STATIONS ARE FOR BOTH THE WARMEST AND COLDEST MONTHS ON RECORD AND ARE THE AVERAGE POSITIONS DURING THOSE MONTHS.

D. DAILY EXTREME TEMPERATURES (MAPS 4 & 5)

OF ALL THE CLIMATIC MAPS IN THE SERIES, THESE TWO WERE BASED ON THE MOST NUMEROUS DATA. RELIABILITY IS GOOD IN MOST AREAS EXCEPT THE INTERIORS OF GREENLAND, SPITZBERGEN, AND ELLESMERE ISLAND. WHILE THE RELIABILITY FOR THESE AREAS IS POOR, IT IS SAFE TO SAY THAT MEAN DAILY MAXIMUM TEMPERATURES RARELY RISE TO THE MELTING POINT ON THE HIGH ICE CAPS. THE ONLY STATIONS HAVING MEAN DAILY MINIMUM TEMPERATURES ABOVE FREEZING IN WINTER ARE KRAKENES ON THE SOUTHWEST COAST OF NORWAY AND THORSHAVN IN THE FAEROE ISLANDS. LINES ON BOTH MAPS ARE DRAWN AT INTERVALS OF 10 F DEGREES. THE PRINCIPAL SOURCES OF DATA ARE LISTED IN THE BIBLIOGRAPHIES OF THE CLIMATIC ANALOG STUDIES (5, 6) AND CLIMATIC INFORMATION SOURCES FOR GREENLAND (7).

(ERRATA: ON MAP 4, THE TWO SMALL 70° ISOTHERMS INCLOSED BY A 60° LINE IN CENTRAL ALASKA SHOULD BE LABELED 50°. ON MAP 5, THE EASTERNMOST -60° ISOTHERM IN SIBERIA SHOULD READ -50°.)

E. TEMPERATURE FREQUENCIES IN JANUARY (MAPS 6, 7, 8, 9, 10, & 11)

MOST OF THE DATA USED TO DRAW THESE SIX MAPS CAME FROM THE SEVERAL VOLUMES OF FREQUENCY TABLES PREPARED BY RAYNER (12, 13), BASED UPON RECORDS OF 2 TO 10 YEARS. THE RELIABILITY OF MUCH OF THIS INFORMATION, ESPECIALLY FOR STATIONS WITH THE SHORTER RECORDS, IS NO BETTER THAN FAIR, AND RELIABILITY OF THE MAPS IS VARIABLE.

Frequencies are shown at 10-percent intervals, with lines for 5 and 95 percent given where applicable. A line designated 0.1 percent has been drawn on each map to delimit areas where the available frequency data revealed no occurrence of temperatures below (or above, in Map 6) the specified value. The complete climatic records contain an occasional measurement beyond the specified limit, but occurrence of such values is below the 0.1-percent level of frequency.

(Erratum: The inclosed 5-percent line in northern Novaya Zemlya should be labeled 20.)

F. Annual freeze-thaw cycles (Map 12)

The lines drawn for Canada are based upon actual data compiled by Williams (18), and the reliability of this portion of the map is fair. For other parts of the world, values were estimated from a nomogram derived from the Canadian data by Dodd (4) and, therefore, are less definitive than those based on actual measurements. The basic temperature data that were applied to the nomogram came from the British Air Ministry (2), Falkowski (5), and Hastings (6).

Isopleths within mountainous regions are shown only to give continuity to the lines. Owing to the scarcity of data and the differences in seasonal occurrence of freeze-thaw cycles between high and low areas within mountainous regions, the isopleths in such regions are not indicative of actual conditions.

In the fractional notation at each station on the map, the numerator indicates those seasons having at least 40 percent of the annual number of cycles while the denominator shows seasons when less than 10 percent occur. Seasons not indicated in the fraction have between 10 and 40 percent of the annual total.

G. Freeze or thaw months (Map 13)

The circular graphs centered on the sites of meteorological stations show those months when freezing conditions (in solid black) or thawing conditions (stippled) can be expected to prevail at least 90 percent of the time. Freeze-thaw cycles would be most common during the months that remain unshaded.

Reliability of the map may be considered only fair inasmuch as all data came from tabulations of relatively short records (12, 13).

H. Freeze-up and break-up of river ice (Maps 14 & 15)

Freeze-up lines (isopectics) and break-up lines (isotacs) are shown for the first and fifteenth day of each applicable month during an average season. The reliability of dates is generally good except where little or no data were available, as in Spitzbergen, Iceland, most of Greenland, and the lesser islands north of the 75th parallel. The period

BETWEEN BREAK-UP AND FREEZE-UP OF THE LARGER STREAMS MAY BE CONSIDERED AS THE NAVIGATIONAL SEASON. THERE ARE YEARS ON RECORD WHEN CERTAIN OF THE NAVIGABLE RIVERS IN SIBERIA HAVE NOT BEEN OPEN TO THE PASSAGE OF SHIPPING THROUGHOUT THE ENTIRE SUMMER.

THE INFORMATION FOR BOTH MAPS WAS DERIVED PRIMARILY FROM U.S. AND BRITISH COASTAL PILOTAGE MANUALS (1, 16) AND ANNUAL CLIMATIC SUMMARIES BY THE U.S. WEATHER BUREAU.

I. SNOW DEPTH (MAP 16)

AVERAGE SNOW DEPTHS FOR THE MONTH OF GREATEST ACCUMULATION ARE SHOWN BY ISOPLETHS DRAWN IN 10-INCH INCREMENTS UP TO A DEPTH OF 80 INCHES. WHERE DEPTHS EXCEED 80 INCHES (IN GREENLAND AND THE ALASKAN HIGHLANDS), 100- AND 120-INCH LINES ARE ALSO INCLUDED. A 5-INCH LINE APPEARS IN THE BARENTS SEA AND AT THE MOUTH OF THE YANA RIVER IN SIBERIA TO EMPHASIZE THOSE SHALLOW SPOTS. FOR CLARITY IN DRAFTING, THE DASHED LINES ALONG THE SOUTHEAST COAST OF GREENLAND ARE SHOWN ONLY BY 20-INCH INTERVALS UP TO 60° NORTH.

MAJOR AREAS OF PERMANENT ICE FIELDS AT HIGHER ELEVATIONS ARE SET APART BY GRAY SHADING TO INDICATE DEPTHS IN EXCESS OF 120 INCHES. THE TERM "ELEVATED ICE FIELDS" DIFFERENTIATES THESE MAJOR CORE AREAS FROM THE MANY VALLEY AND PIEDMONT GLACIERS AND MINOR ICE FIELDS THAT COULD NOT BE SHOWN.

RELIABILITY OF THE MAP IS FAIR TO GOOD THROUGHOUT. ALL DATA WERE TAKEN FROM FALKOWSKI (5) AND HASTINGS (6).

J. PRECIPITATION FREQUENCY IN SUMMER (MAPS 17, 18, 19)

THE MEAN MONTHLY NUMBER OF DAYS WITH OCCURRENCE OF AT LEAST 0.01 INCH OF PRECIPITATION IS SHOWN BY ISOPLETHS IN 2-DAY INCREMENTS FOR JUNE, JULY, AND AUGUST. THE BASIC DATA FOR GREENLAND AND SIBERIA HAD TO BE ADJUSTED FROM FREQUENCIES GIVEN IN METRIC UNITS (EQUIVALENTS OF 0.04 AND 0.004 INCH). ELSEWHERE THE RELIABILITY OF THE LINES IS GOOD.

THE DATA CAME MAINLY FROM SUMMARIES BY THE U.S. AND CANADIAN WEATHER BUREAUS, AND FROM THE BRITISH AIR MINISTRY TABLES (2).

(ERRATA: IN ALASKA, THE INCLOSED 14-DAY LINE ON THE KENAI PENINSULA AND 16-DAY LINE IN THE PANHANDLE SHOULD BOTH BE LABELED 12.)

K. ANNUAL PRECIPITATION (MAP 20)

ISOHYETS ARE DRAWN AT 5-INCH INTERVALS UP TO 25 INCHES PER YEAR. IN WETTER AREAS, UP TO THE MAXIMUM OF 222 INCHES IN THE ALASKAN PANHANDLE, THE INTERVAL IS INCREASED TO 25 INCHES.

THE INFORMATION ON THIS MAP HAS GOOD RELIABILITY IN ALL AREAS EXCEPT THE ICECAPPED ARCTIC ISLANDS, WHERE IT SHOULD BE REGARDED AS VERY POOR. ALL DATA WERE DERIVED FROM FALKOWSKI (5) AND HASTINGS (6).

L. Frequencies of Strong Winds in Winter and Summer (Maps 21 and 22)

These maps show the percent of surface winds of at least 25 miles per hour during three winter months and three summer months. Lines are shown in 10-percent increments and at 5-, 1-, and 0-percent levels. The zero line is given to exclude those areas where the available period of record showed no occurrence of winds this strong.

Wind arrows indicate the prevailing direction for all surface winds during the three-month periods. These are not necessarily the same directions as those from which the winds exceeding 25 miles per hour customarily originate.

Owing to the short periods of frequency records and the local nature of wind conditions, the reliability of the lines on these two maps is poor to fair. The data came primarily from Rayner (12,13).

3. Acknowledgments

Map 2 (Vegetation Zones) was prepar[illegible] by Dr. William C. Robison, Geographer. Maps 12 and 13 (Frequencies of Freeze-Thaw Cycles and 90 Percentile Freeze or Thaw Months) were prepared by Mr. Arthur V. Dodd, Meteorologist. The final ink drawings were rendered by Mr. Aubrey Greenwald, Cartographer.

4. References

1. British Admiralty, Hydrographic Office, Arctic Pilot, volumes for various coastal areas, HM Stationery Office, London (most recent years available).

2. British Air Ministry, Meteorological Office, Tables of Temperature, Relative Humidity & Precipitation for the World, Parts I, [illegible], and V, (M.O. 617a, 617c, & 617e), HM Stationery Office, London, 1958

3. Canadian Dept. of Mines & Technical Surveys, Geographical Branch, Atlas of Canada, (Pl.38, "Natural Vegetation & Flora" and Pl.39, "Forest Regions"), Ottawa, 1957.

4. Dodd, A.V., Nomogram for Estimating Monthly Frequency of Freeze-Thaw Cycles from Mean and Extreme Temperatures and Mean Daily Temperature Range, QM R&E Command, Natick, Mass., (unpublished).

*5. Falkowski, S.J., Climatic Analogs of Fort Greely, Alaska, and Fort Churchill, Canada, in Eurasia, Tech. Rpt., EP-77, QM R&E Command, Natick, Dec 1957.

*6. Hastings, A.D., Jr., Climatic Analogs of Fort Greely, Alaska, and Fort Churchill, Canada, in North America, Tech. Rpt. EP-111, QM R&E Command, Natick, May 1959.

*7. Hastings, A.D., Jr., Climatic Information Sources for Greenland, Research Study Rpt. RER-11, QM R&E Command, Natick, Jan 1957.

*8. Hastings, A.D., Jr., Environment of Southeast Greenland, Tech. Rpt. EP-140, QM R&E Command, Natick, Oct 1960.

9. Lobeck, A.K., Physiographic Diagram of Asia and Physiographic Diagram of North America, The Geographical Press, Columbia Univ., N.Y., 1950.

10. National Weather Records Center, Tabulations of Climatic Data, Asheville, N.C., 1950-60.

11. Polunin, N.V., Circumpolar Arctic Flora, Clarendon Press, Oxford, 1959.

12. Rayner, J.N. (ed.), Temperature and Wind Frequency Tables for Eurasia, 4 vols. Arctic Meteorology Research Group, McGill University, Montreal, 1960.

13. Rayner, J.N. (ed.), Temperature and Wind Frequency Tables for North America and Greenland, 2 vols, Arctic Meteorology Research Group, McGill University, Montreal, 1960.

14. Shabad, T. (ed.), Soviet Geography: Review & Translation, Vol. 1, No. 1, p. 2, American Geographical Society, N.Y., Jan 1960.

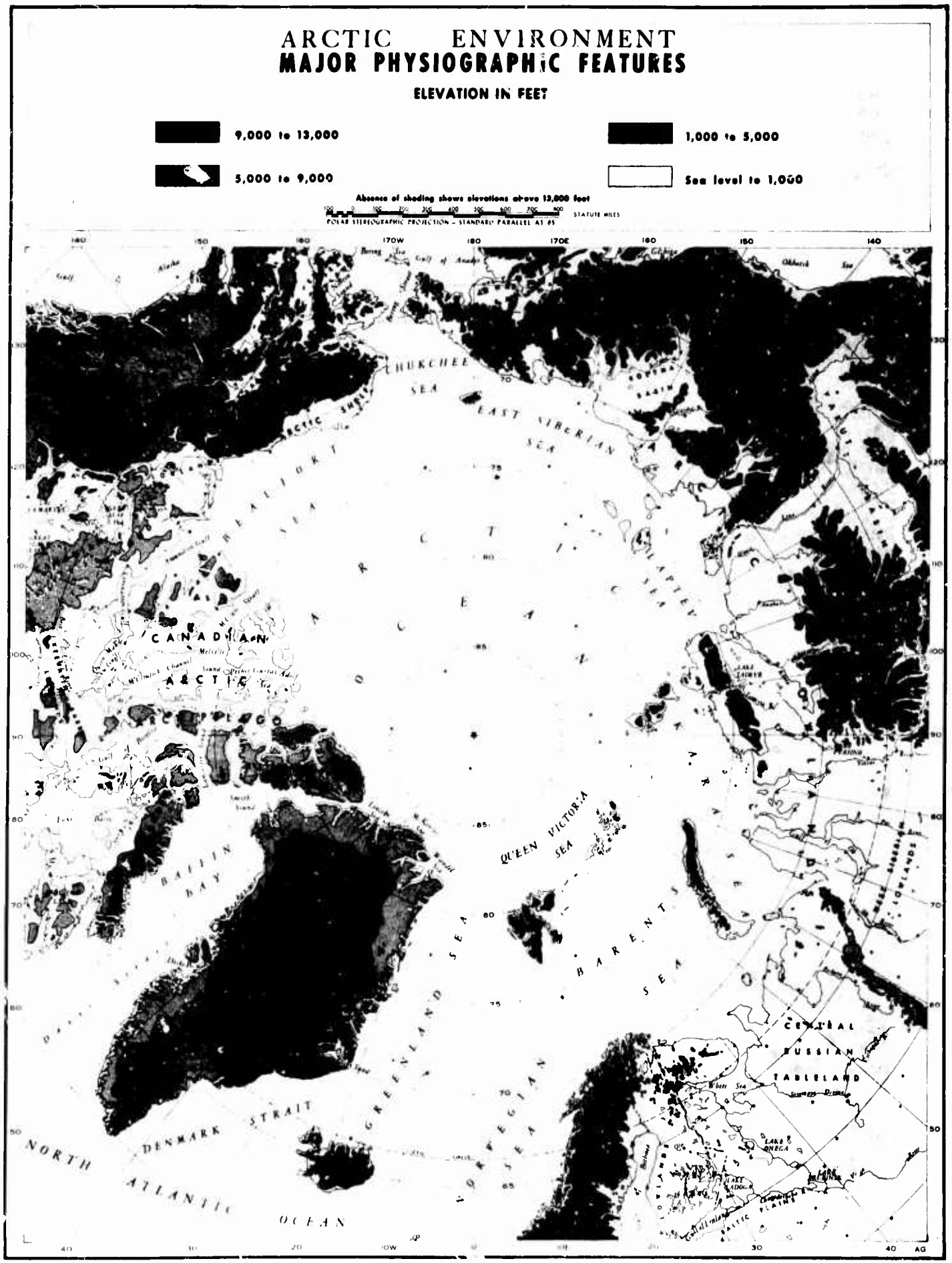
15. Sigafoos, R.S., Vegetation of Northwestern North America, U.S. Geol. Surv. Bull. 1061-E, Washington, 1958.

16. U.S. Navy Department, Hydrographic Office, Sailing Directions, volumes for various coastal areas, U.S. Government Printing Office, Washington, (most recent years available).

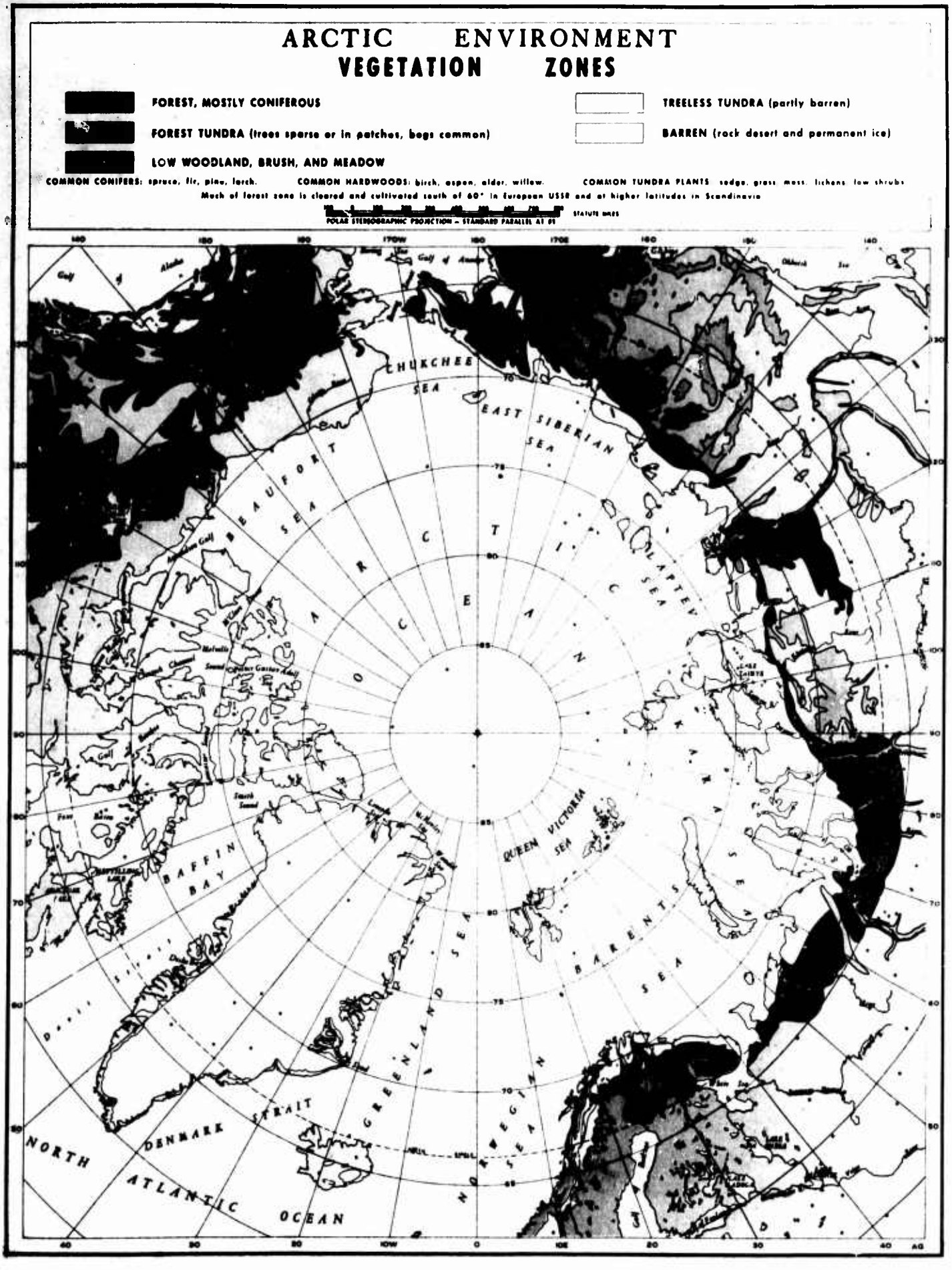
17. U.S.S.R., Bolshoy Sovetskiy Atlas Mira, Moscow, 1954.

*18. Williams, L., Freeze-Thaw as a Climatological Parameter, PhD dissertation, Boston University, Boston, 1960.

*See Introduction

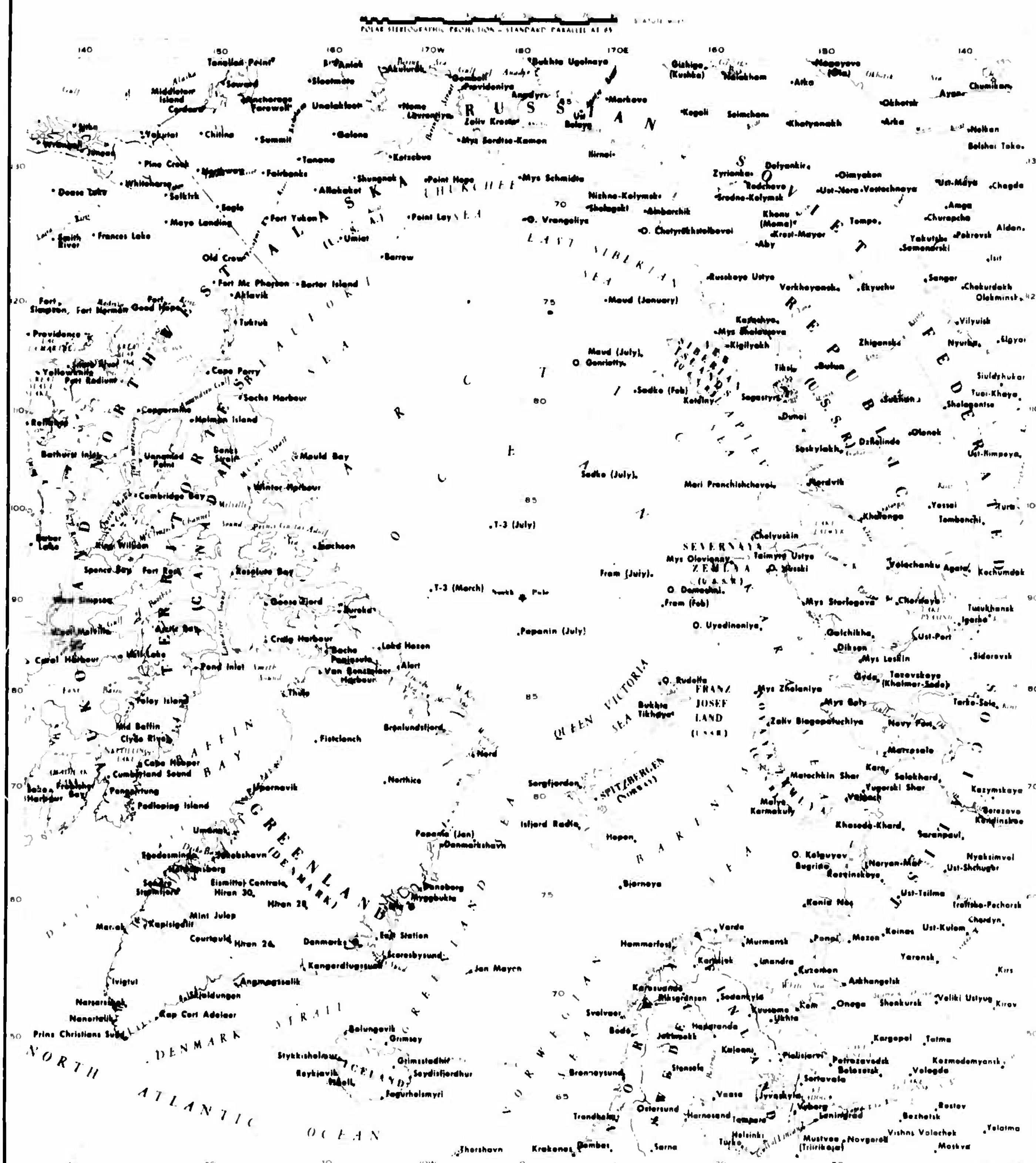

ARCTIC ENVIRONMENT
MAJOR PHYSIOGRAPHIC FEATURES
ELEVATION IN FEET
9,000 to 13,000
5,000 to 9,000
1,000 to 5,000
Sea level to 1,000
Absence of shading shows elevations above 13,000 feet
STATUTE MILES
POLAR STEREOGRAPHIC PROJECTION – STANDARD PARALLEL AT 65
CHUKCHEE SEA
EAST SIBERIAN SEA
BEAUFORT SEA
ARCTIC OCEAN
CANADIAN ARCTIC
QUEEN VICTORIA SEA
BARENTS SEA
BAFFIN BAY
GREENLAND SEA
NORWEGIAN SEA
DENMARK STRAIT
NORTH ATLANTIC OCEAN
CENTRAL RUSSIAN TABLELAND
LAKE ONEGA
LAKE LADOGA
BALTIC

ARCTIC ENVIRONMENT
VEGETATION ZONES



ARCTIC ENVIRONMENT

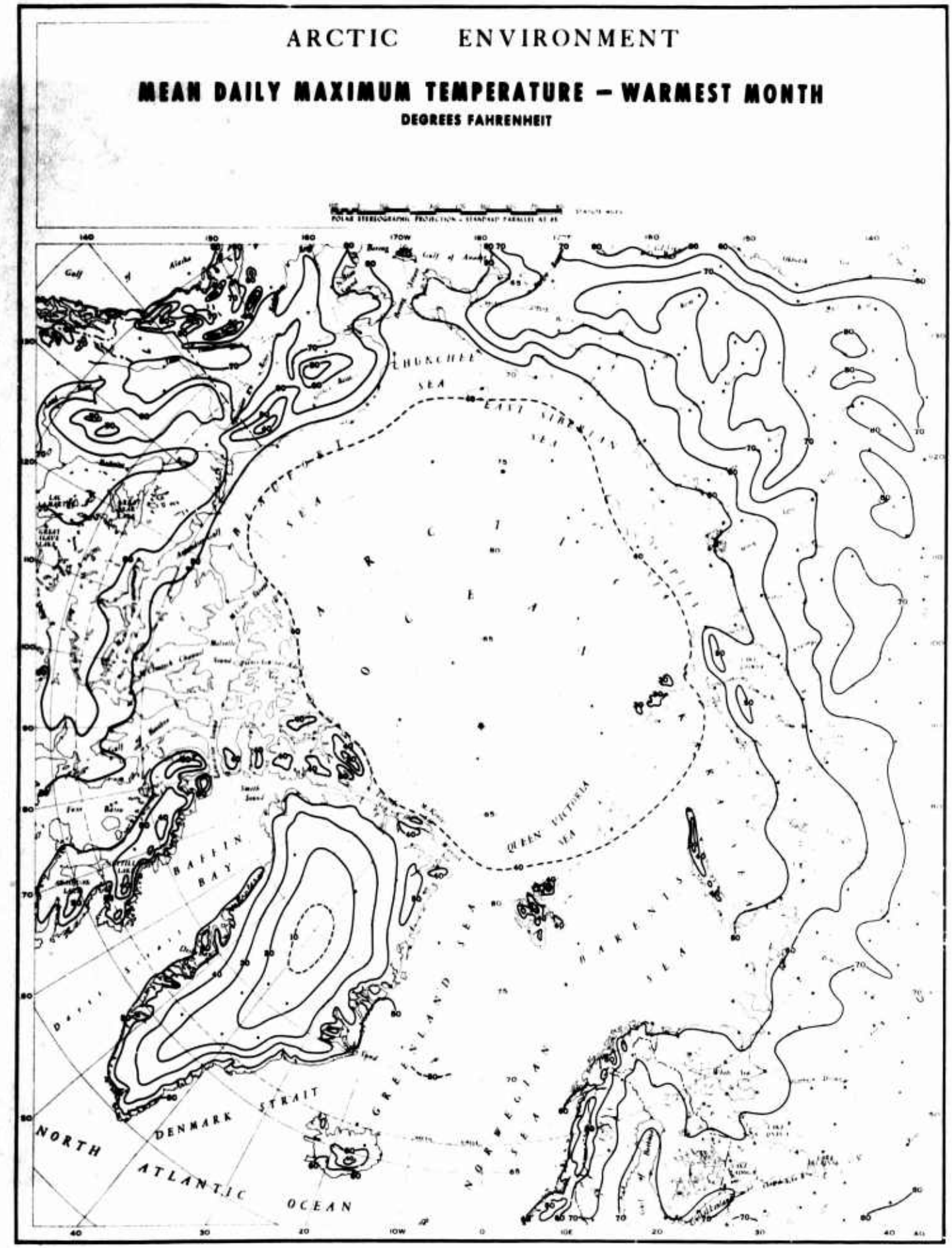
STATION LOCATIONS AND POLITICAL DIVISIONS



ARCTIC ENVIRONMENT

MEAN DAILY MAXIMUM TEMPERATURE – WARMEST MONTH

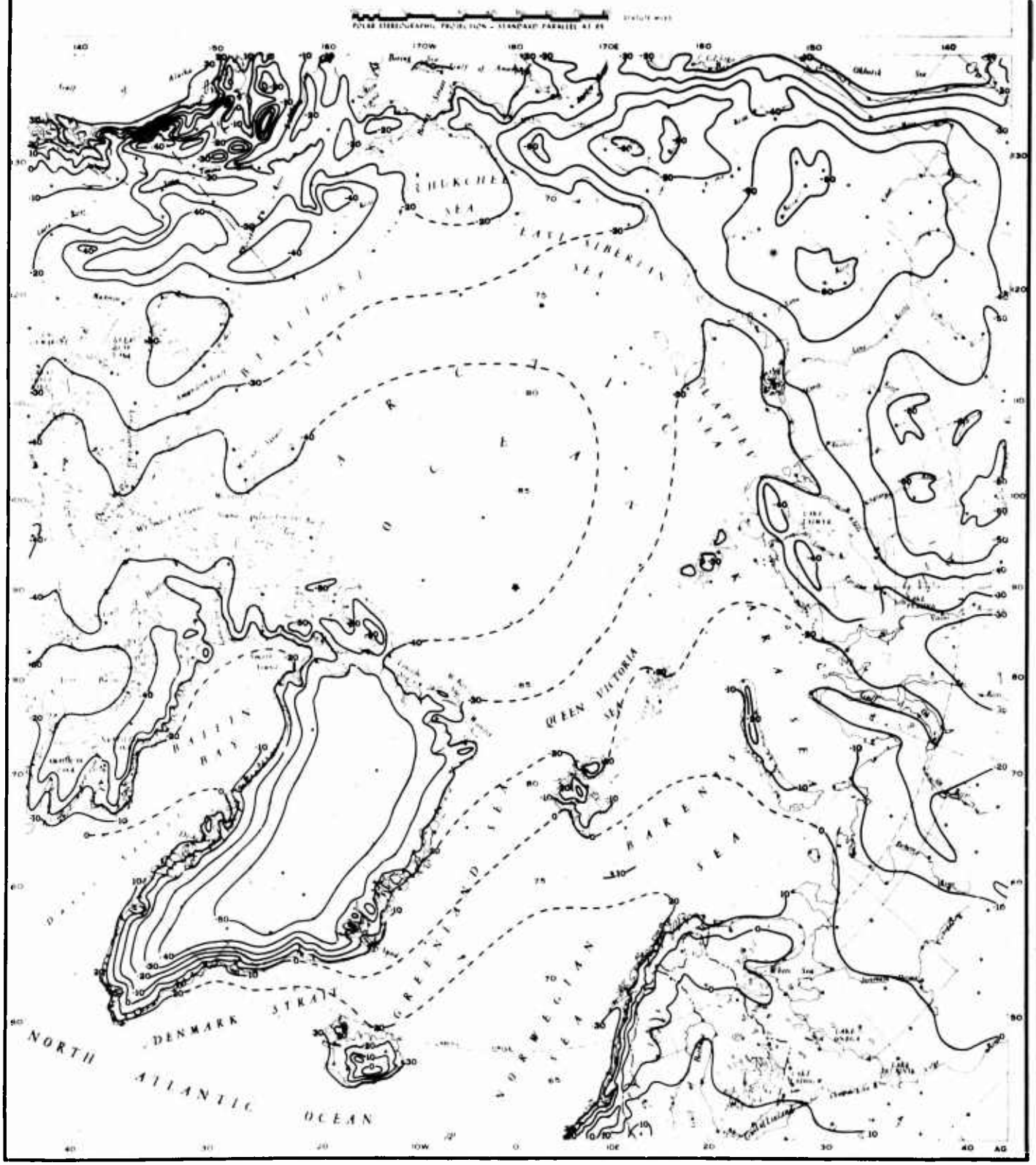
DEGREES FAHRENHEIT



ARCTIC ENVIRONMENT

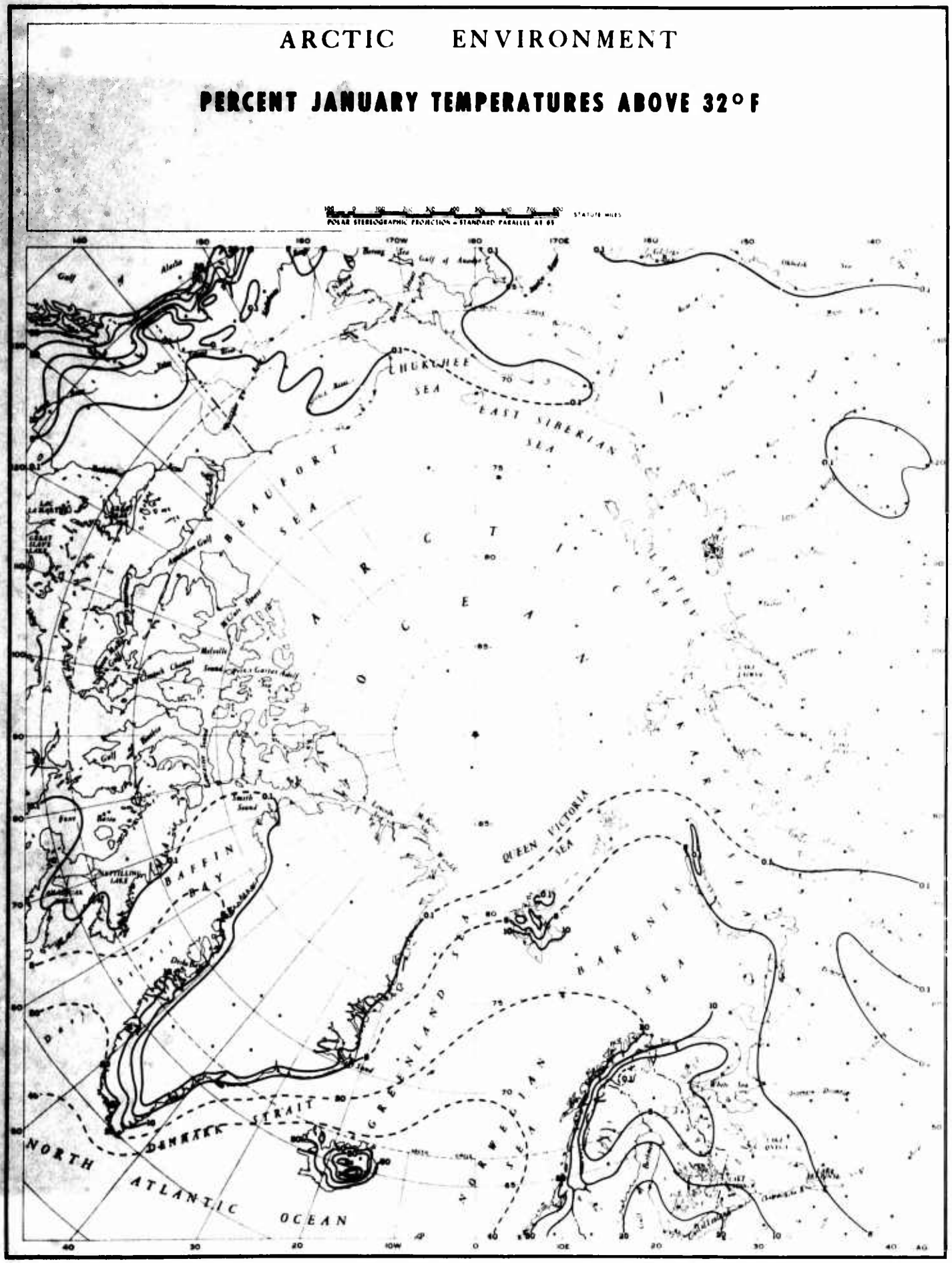
MEAN DAILY MINIMUM TEMPERATURE – COLDEST MONTH

DEGREES FAHRENHEIT



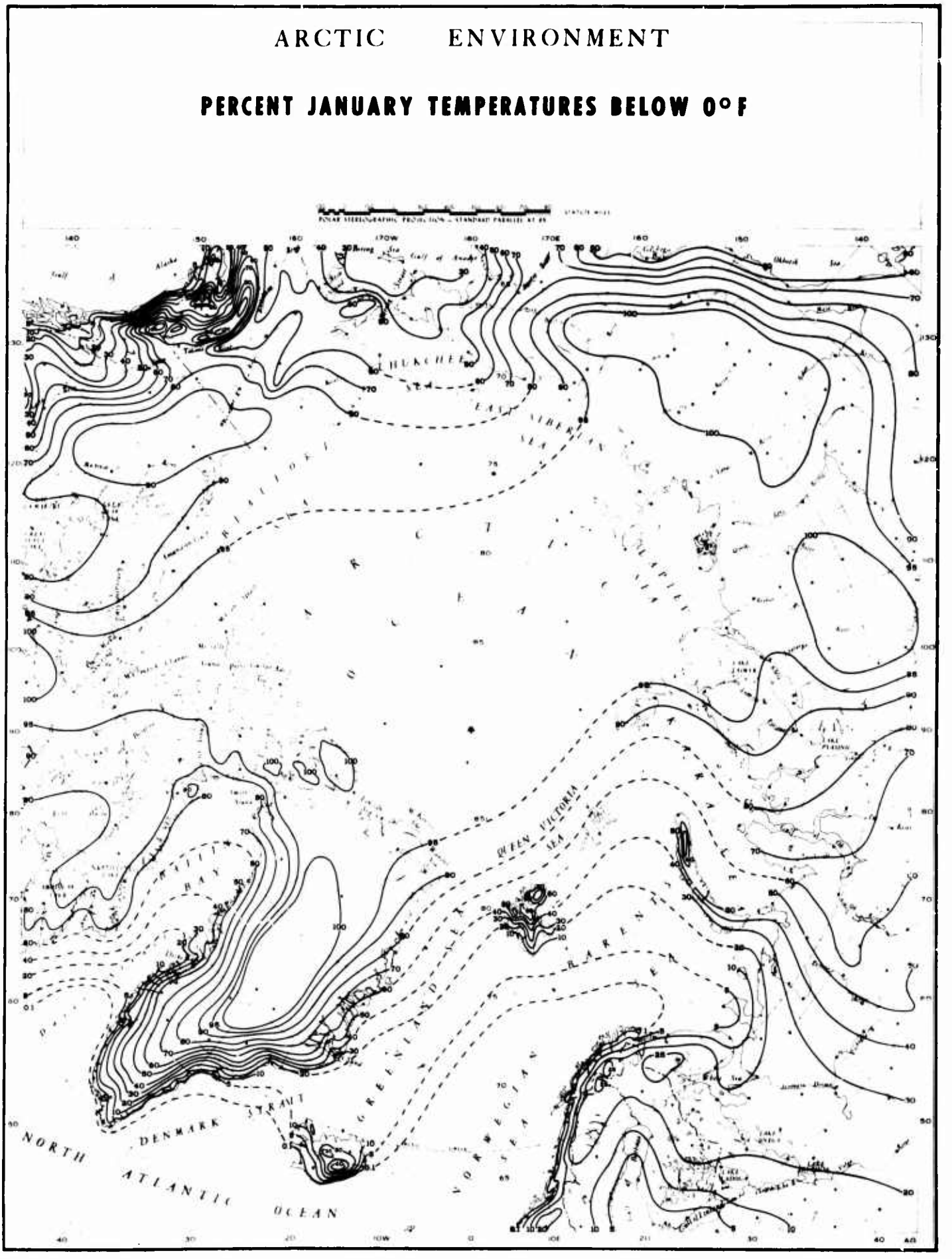
ARCTIC ENVIRONMENT

PERCENT JANUARY TEMPERATURES ABOVE 32° F



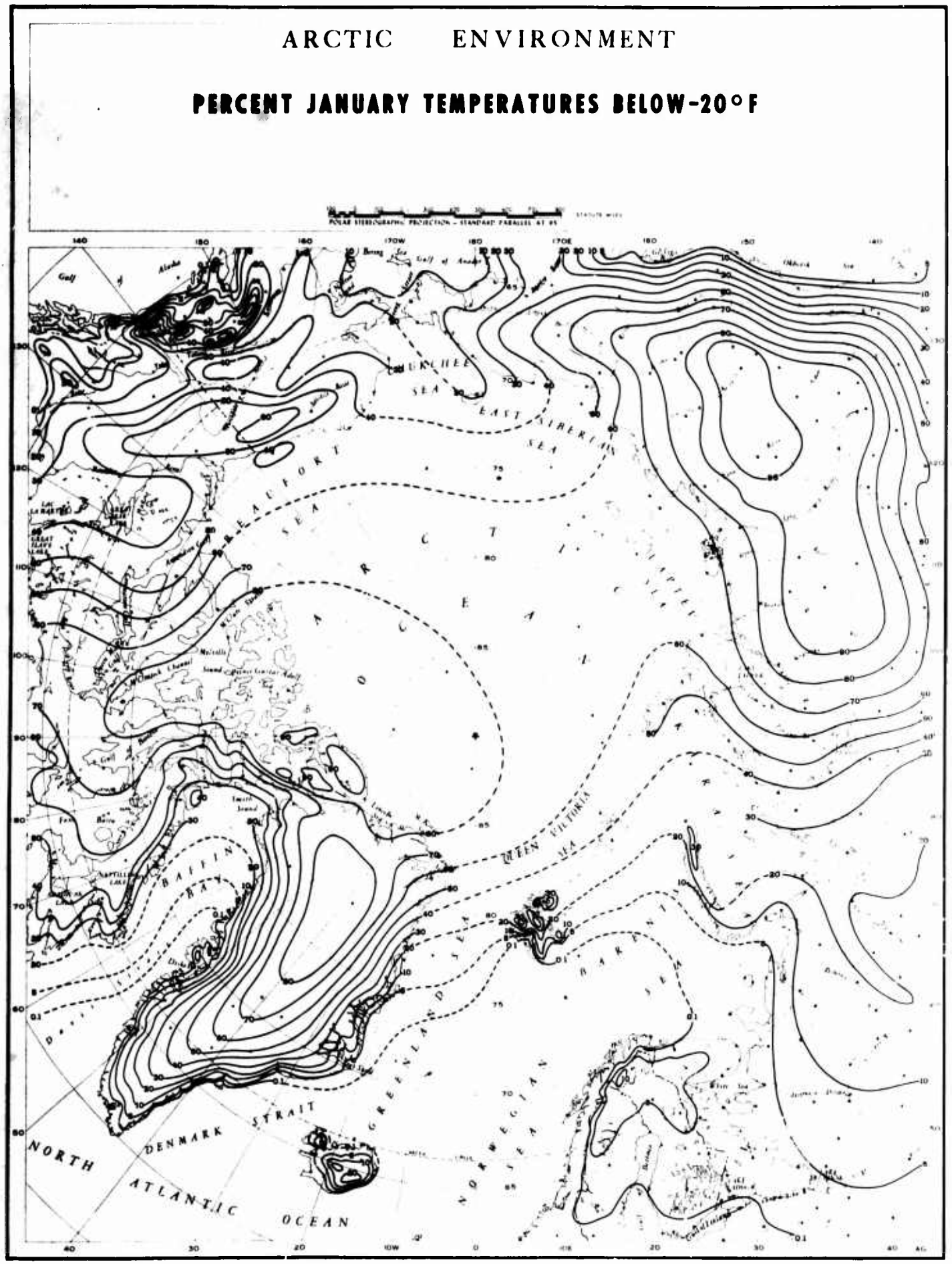
ARCTIC ENVIRONMENT

PERCENT JANUARY TEMPERATURES BELOW 0° F



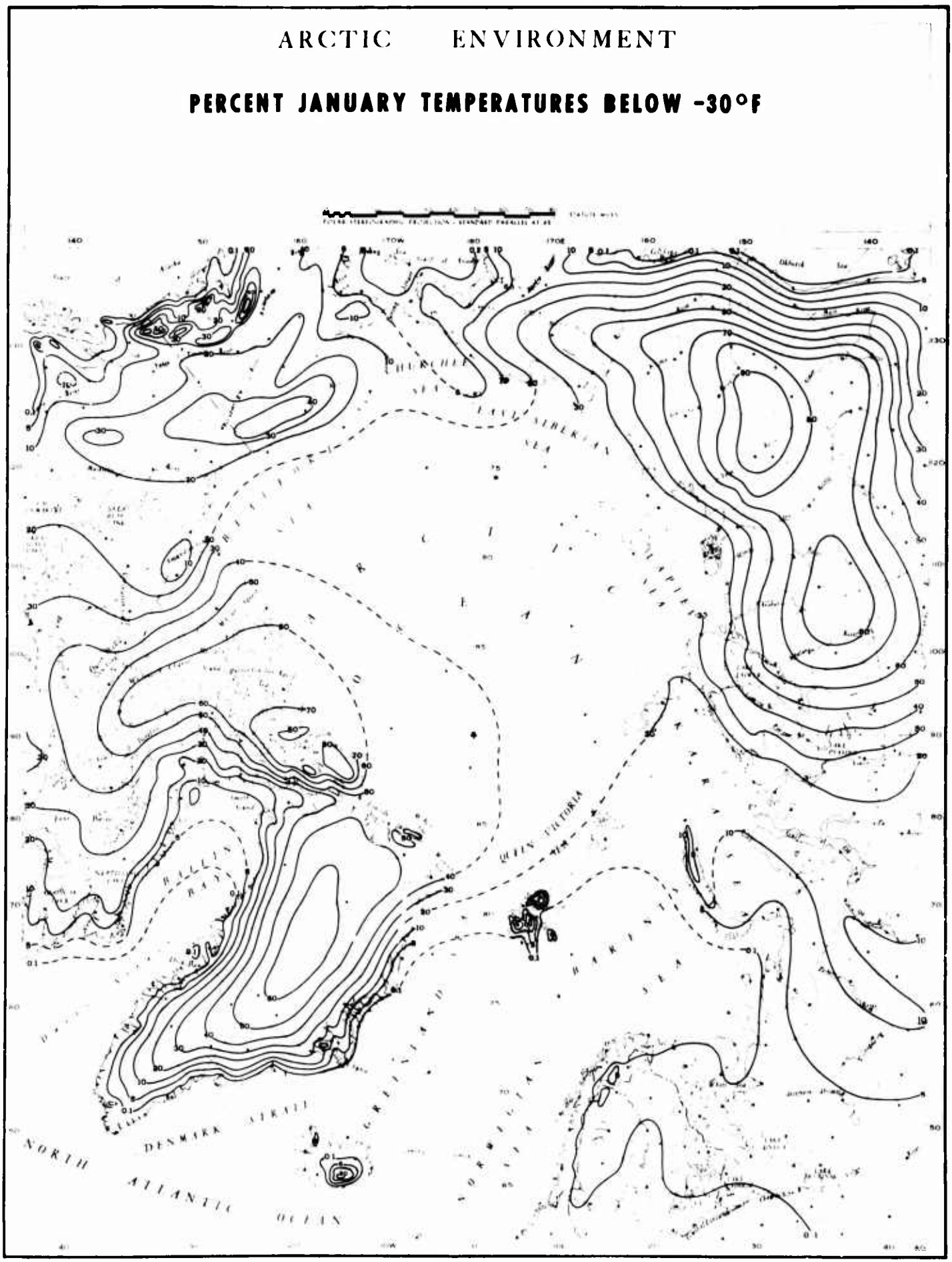
ARCTIC ENVIRONMENT

PERCENT JANUARY TEMPERATURES BELOW -20°F



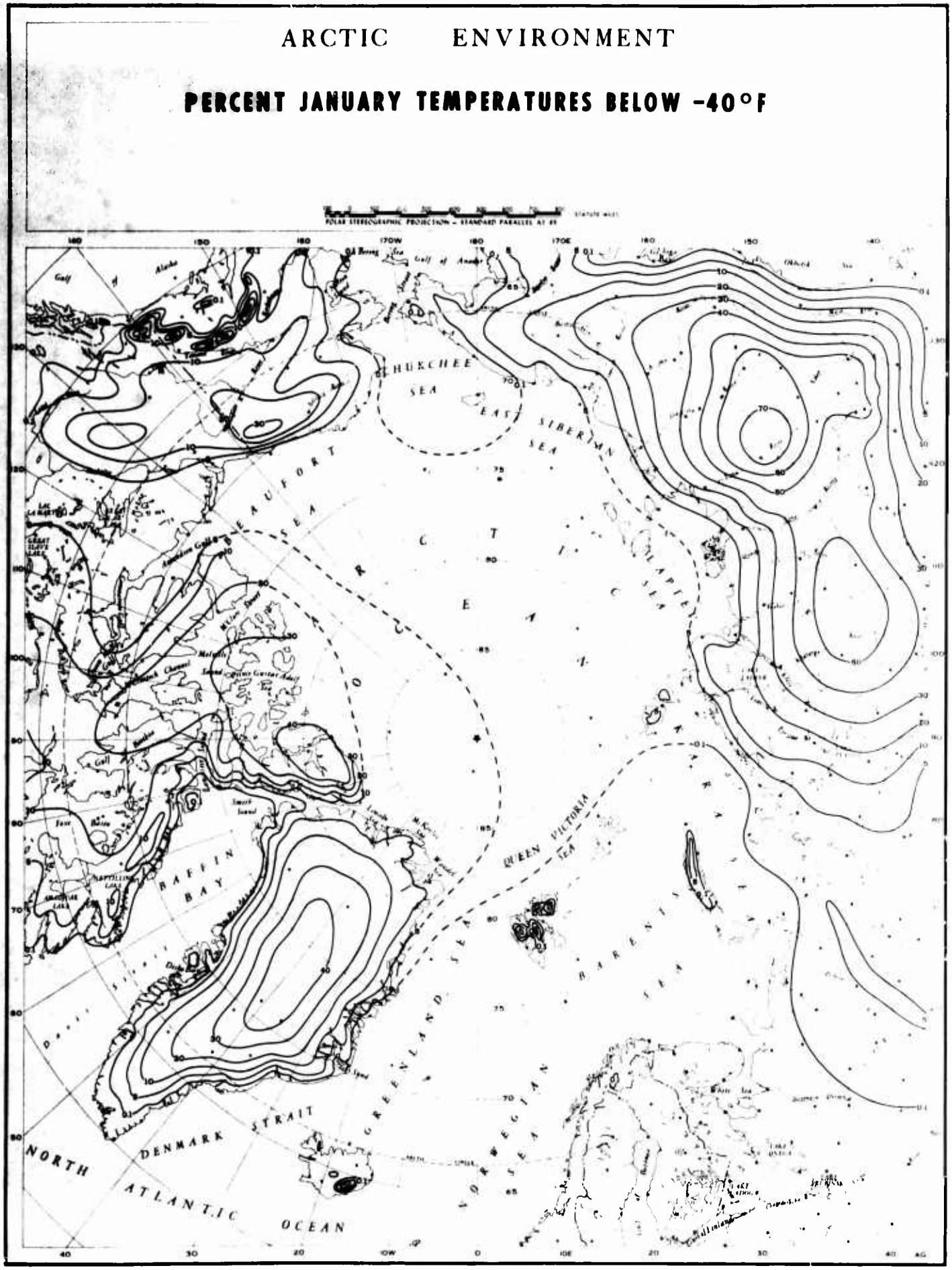
ARCTIC ENVIRONMENT

PERCENT JANUARY TEMPERATURES BELOW -30°F



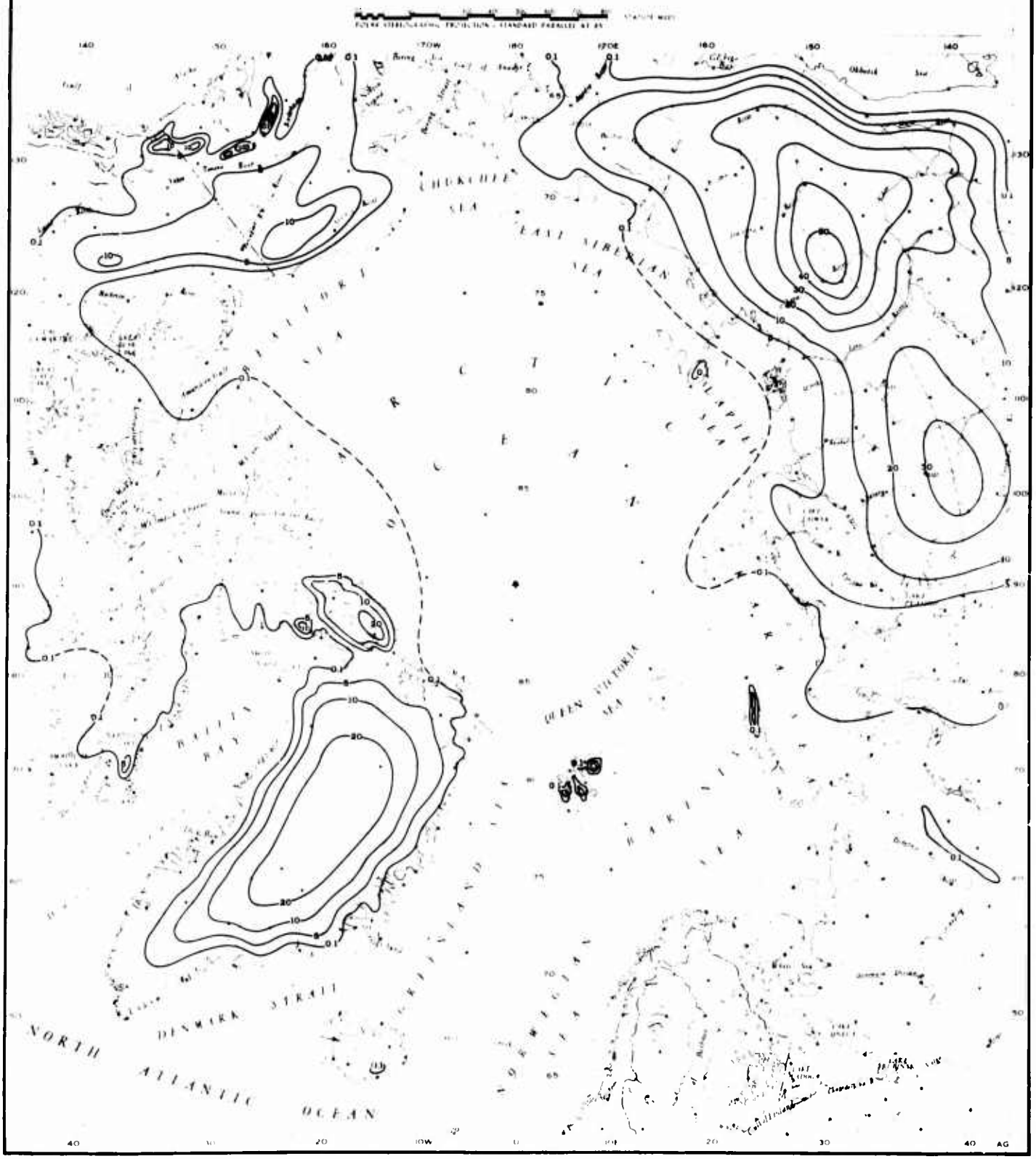
ARCTIC ENVIRONMENT

PERCENT JANUARY TEMPERATURES BELOW -40°F



ARCTIC ENVIRONMENT

PERCENT JANUARY TEMPERATURES BELOW -50°F



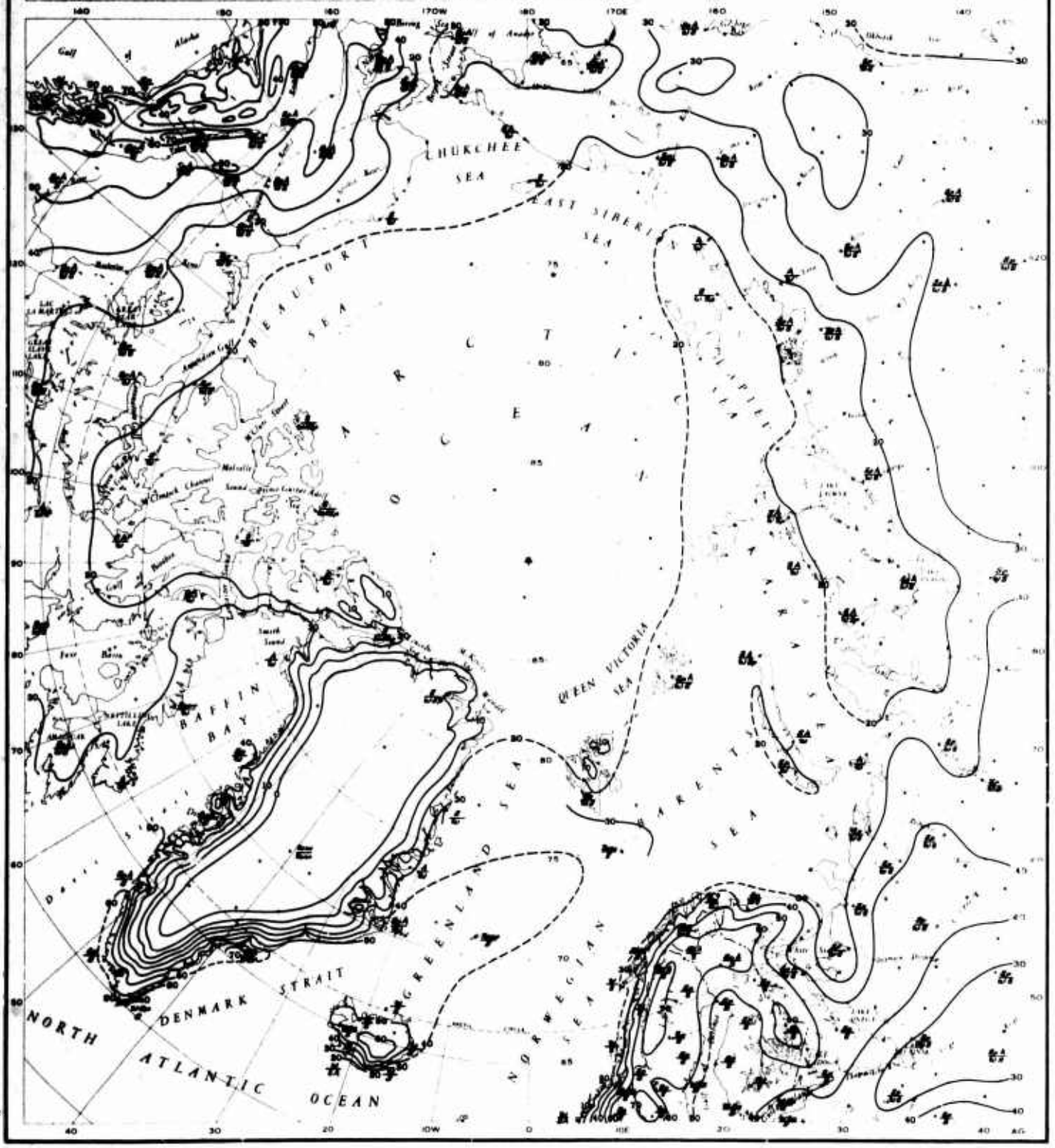
ARCTIC ENVIRONMENT
ANNUAL NUMBER OF FREEZE-THAW CYCLES

FREEZE-THAW CYCLES (AS CALCULATED BY WILLIAMS FOR CANADA AND DERIVED FROM NOMOGRAM FOR OTHER AREAS) ARE DEFINED AS FOLLOWS:
FREEZE CYCLE 34°F OR WARMER DROPPING TO 28° AND RETURNING TO 34°
THAW CYCLE 28°F OR COOLER RISING TO 34° AND RETURNING TO 28°

STATION NOTATIONS INDICATE HIGH AND LOW SEASONAL PERCENT OF TOTAL ANNUAL OCCURRENCE AS IN THE FOLLOWING SAMPLE:

Sp A / W S = • = Spring and Autumn = 40% each; Winter and Summer = 10% each

POLAR STEREOGRAPHIC PROJECTION – STANDARD PARALLEL AT 65



ARCTIC ENVIRONMENT

90 PERCENTILE FREEZE OR THAW MONTHS

SAMPLE STATION

Below 32° F

Above 32° F

DURING AN AVERAGE YEAR, TEMPERATURES AT THE SAMPLE STATION ARE BELOW FREEZING 90% OF THE TIME THROUGHOUT THE MONTHS, NOVEMBER - MARCH, AND ABOVE FREEZING 90% OF THE TIME THROUGHOUT THE MONTHS OF JULY AND AUGUST

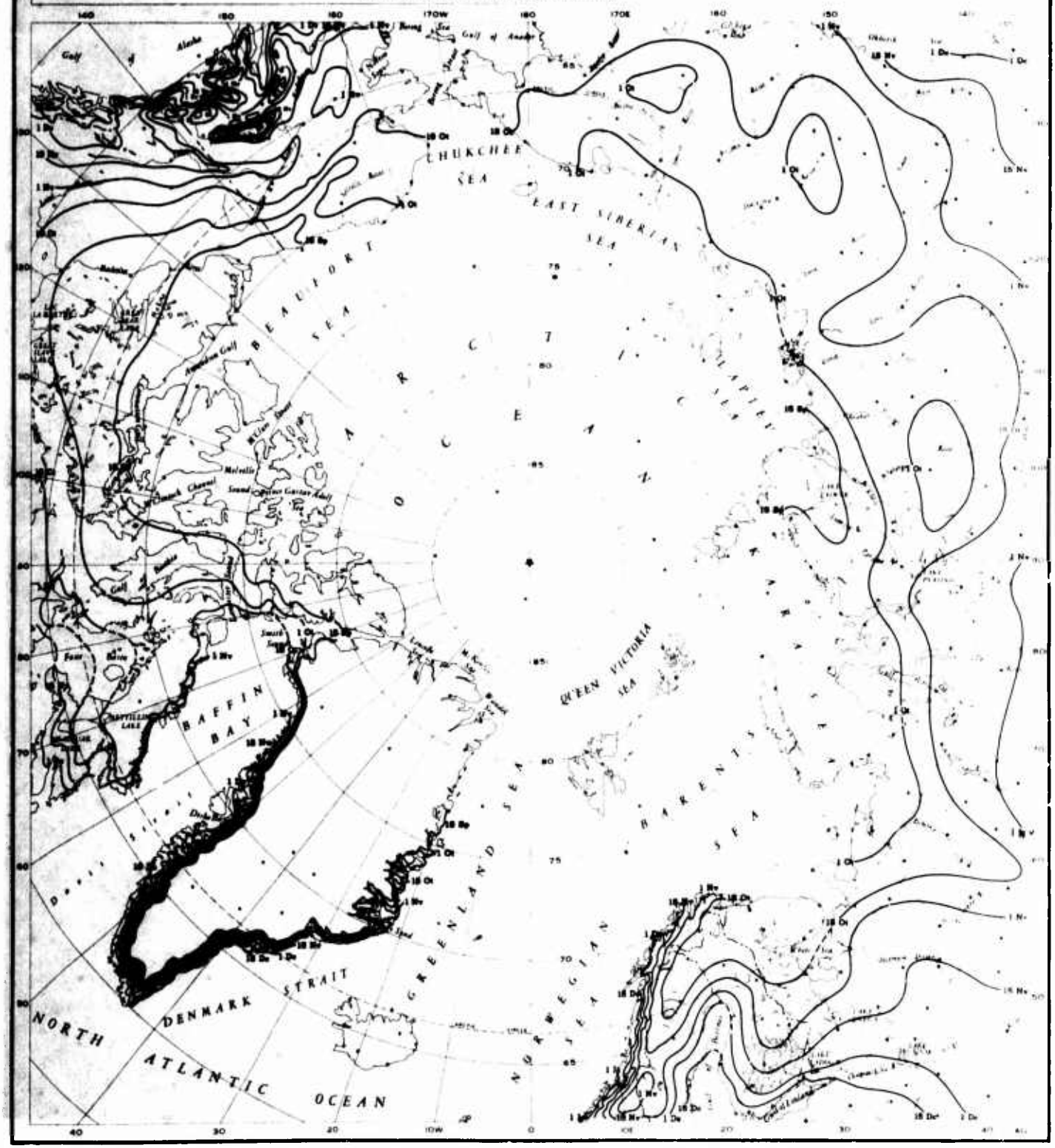
ARCTIC ENVIRONMENT

MEAN FREEZE-UP* DATE FOR RIVER ICE

*FREEZE-UP DEFINED AS END OF NAVIGATION SEASON; MINIMUM ICE THICKNESS OF SIX INCHES (Safe for all dismounted travel). FOR EACH ADDITIONAL SIX INCHES OF THICKNESS, ADD APPROXIMATELY 22 DAYS UP TO MID-FEBRUARY

Dates of lake / ... freeze-up are approximately 15 days earlier

Sp-September, Oc-October, Nv-November, Dc-December



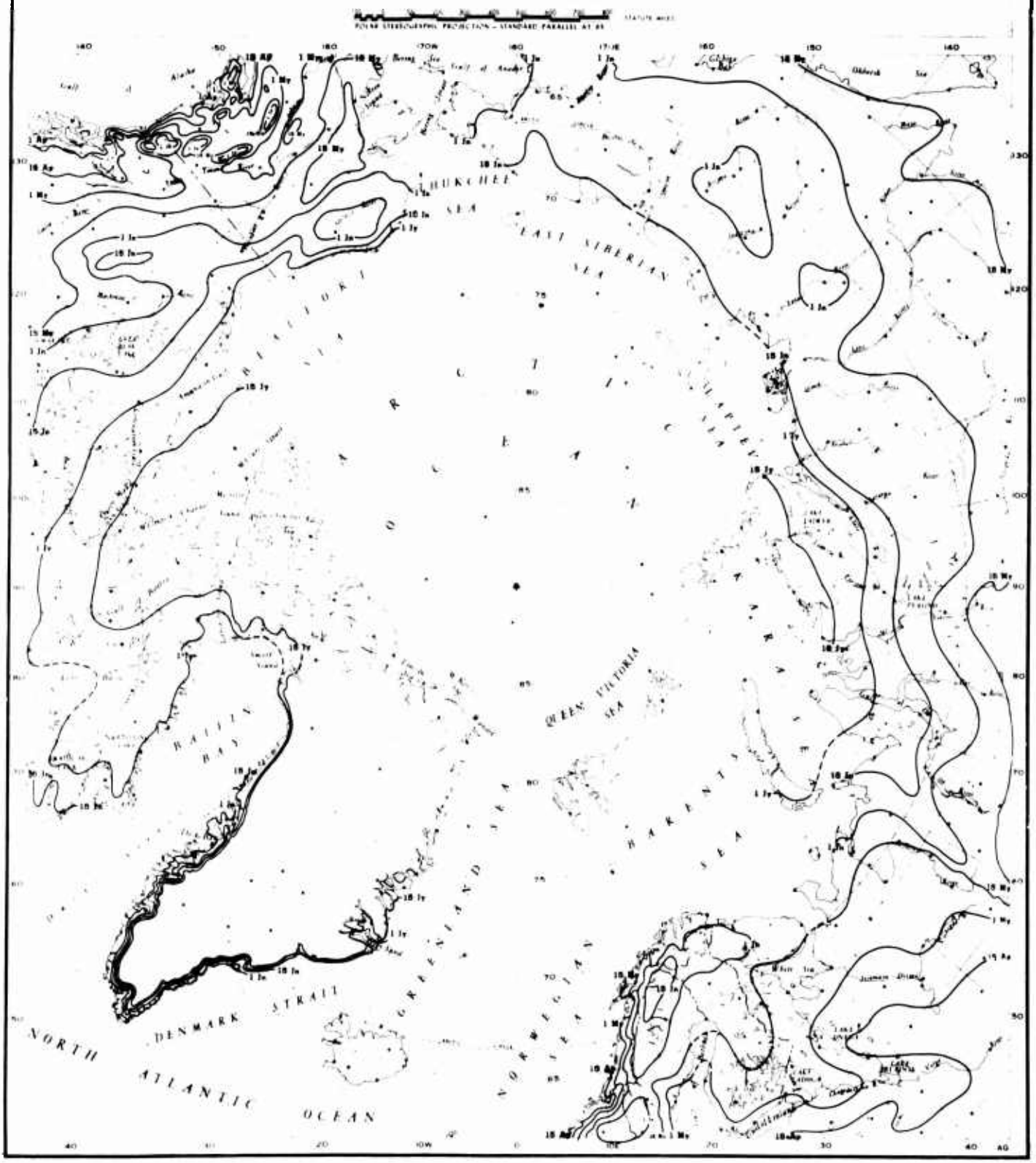
ARCTIC ENVIRONMENT

MEAN BREAK-UP* DATE FOR RIVER ICE

*BREAK-UP DEFINED AS OPENING OF NAVIGATION SEASON: ICE BECOMES UNSAFE FOR FOOT TRAVEL AND TOTALLY DISAPPEARS WITHIN A FEW DAYS. FOR EACH SIX INCHES OF FORMER THICKNESS, SUBTRACT APPROXIMATELY 12 DAYS BACK TO MID-FEBRUARY

Dates of lake ice break-up are approximately 20 days later

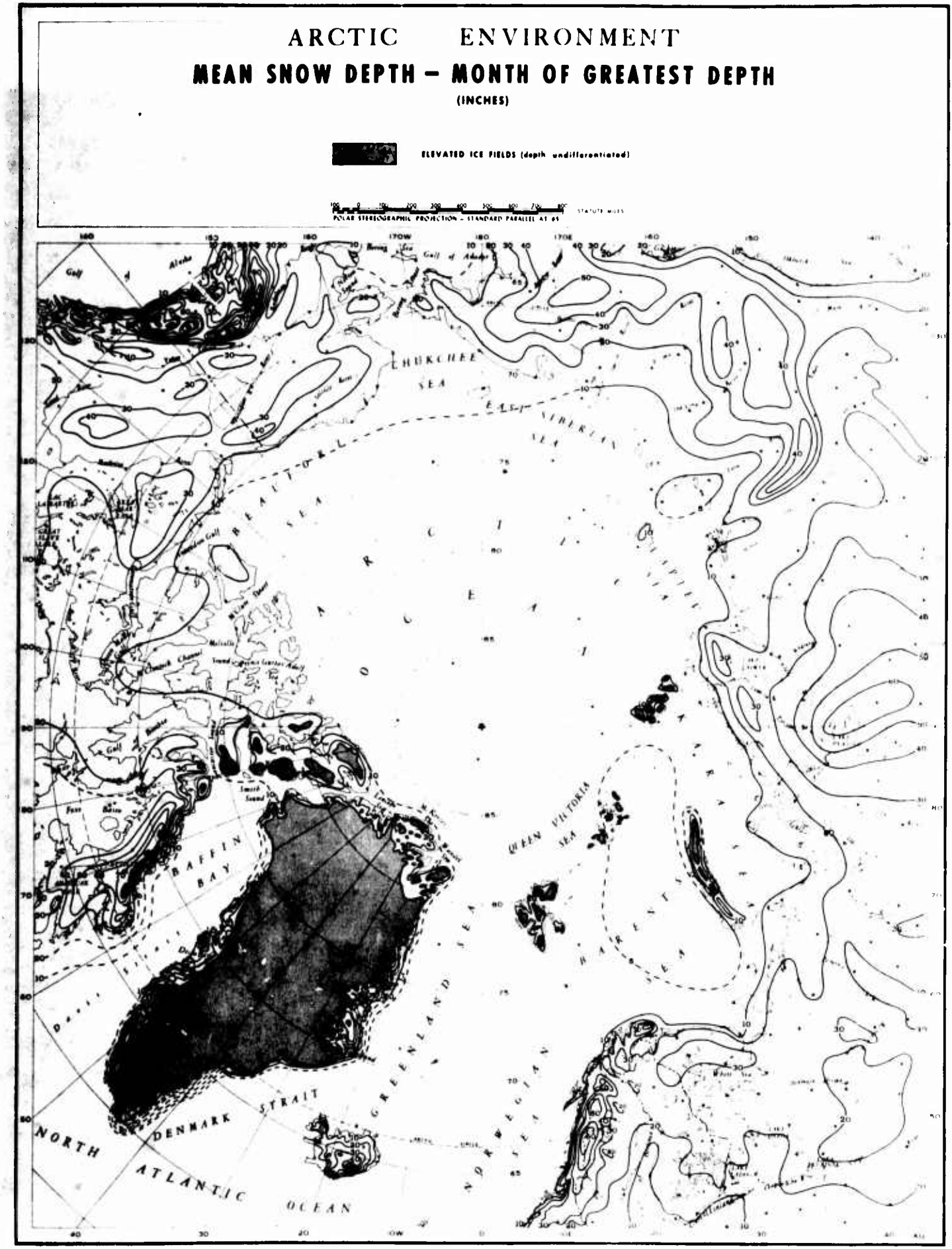
Ap-April, My-May, Jn-June, Jy-July



ARCTIC ENVIRONMENT

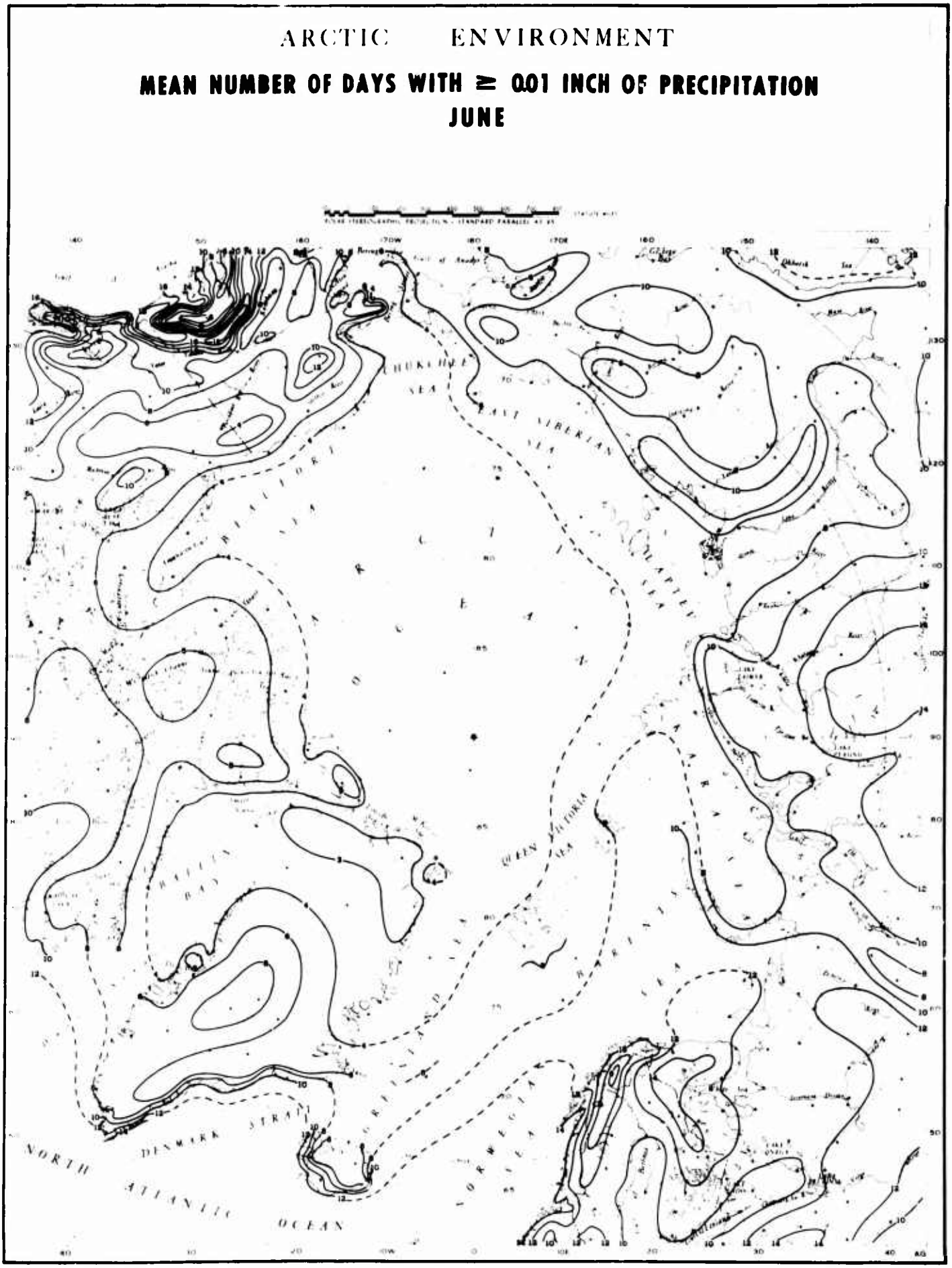
MEAN SNOW DEPTH – MONTH OF GREATEST DEPTH

(INCHES)



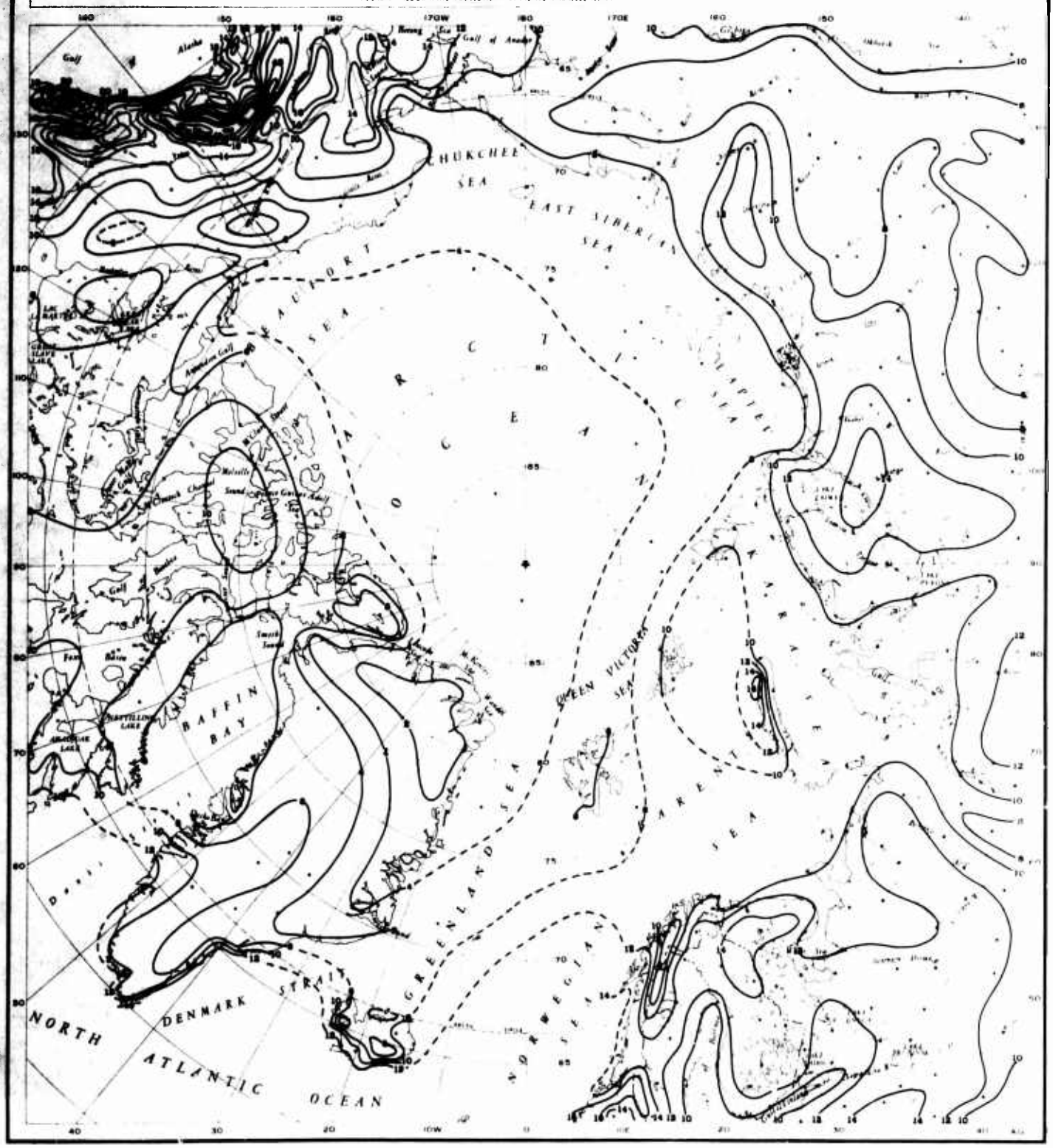
ARCTIC ENVIRONMENT

MEAN NUMBER OF DAYS WITH ≥ 0.01 INCH OF PRECIPITATION
JUNE



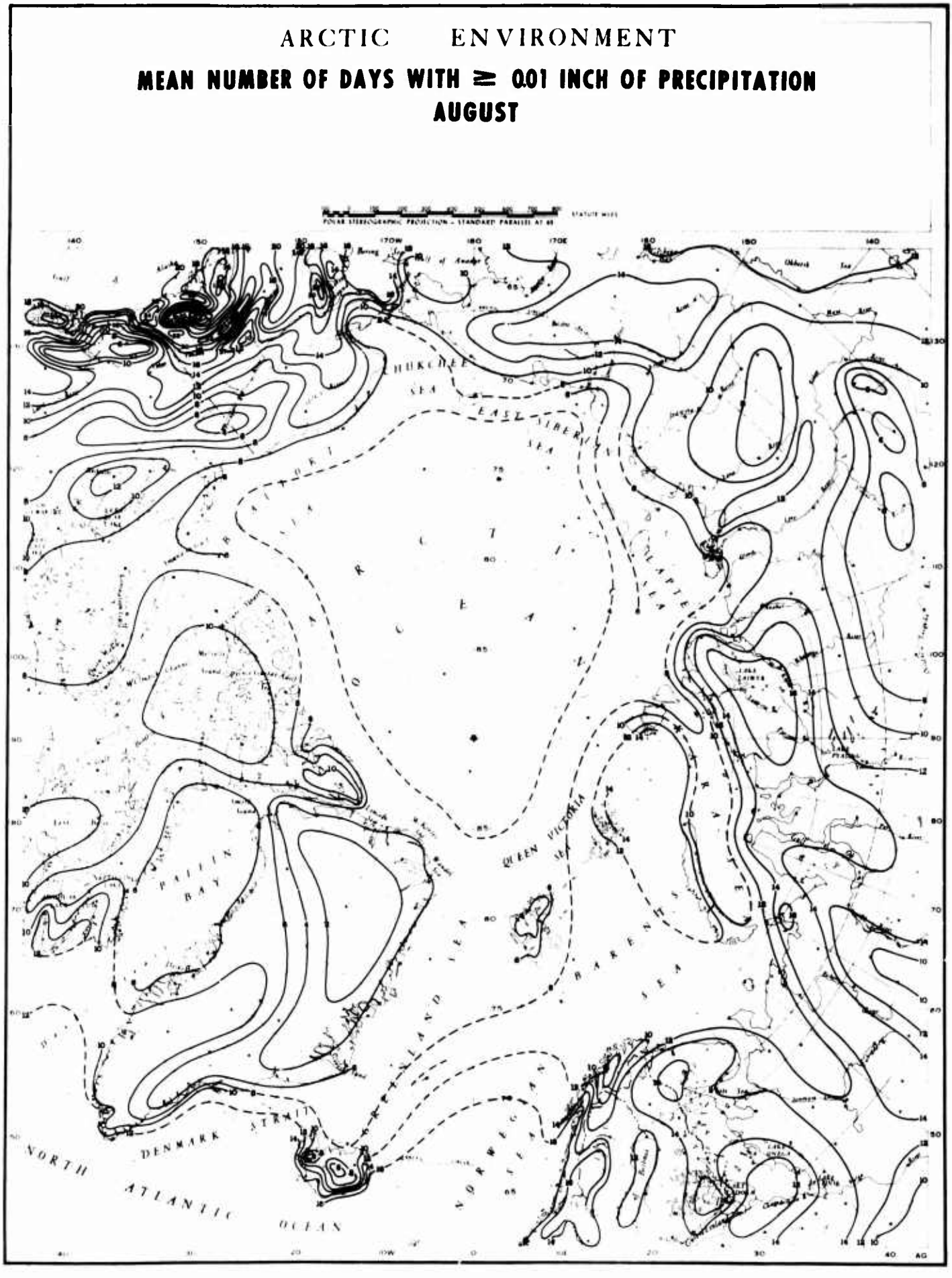
ARCTIC ENVIRONMENT

MEAN NUMBER OF DAYS WITH ≥ 0.01 INCH OF PRECIPITATION JULY



ARCTIC ENVIRONMENT

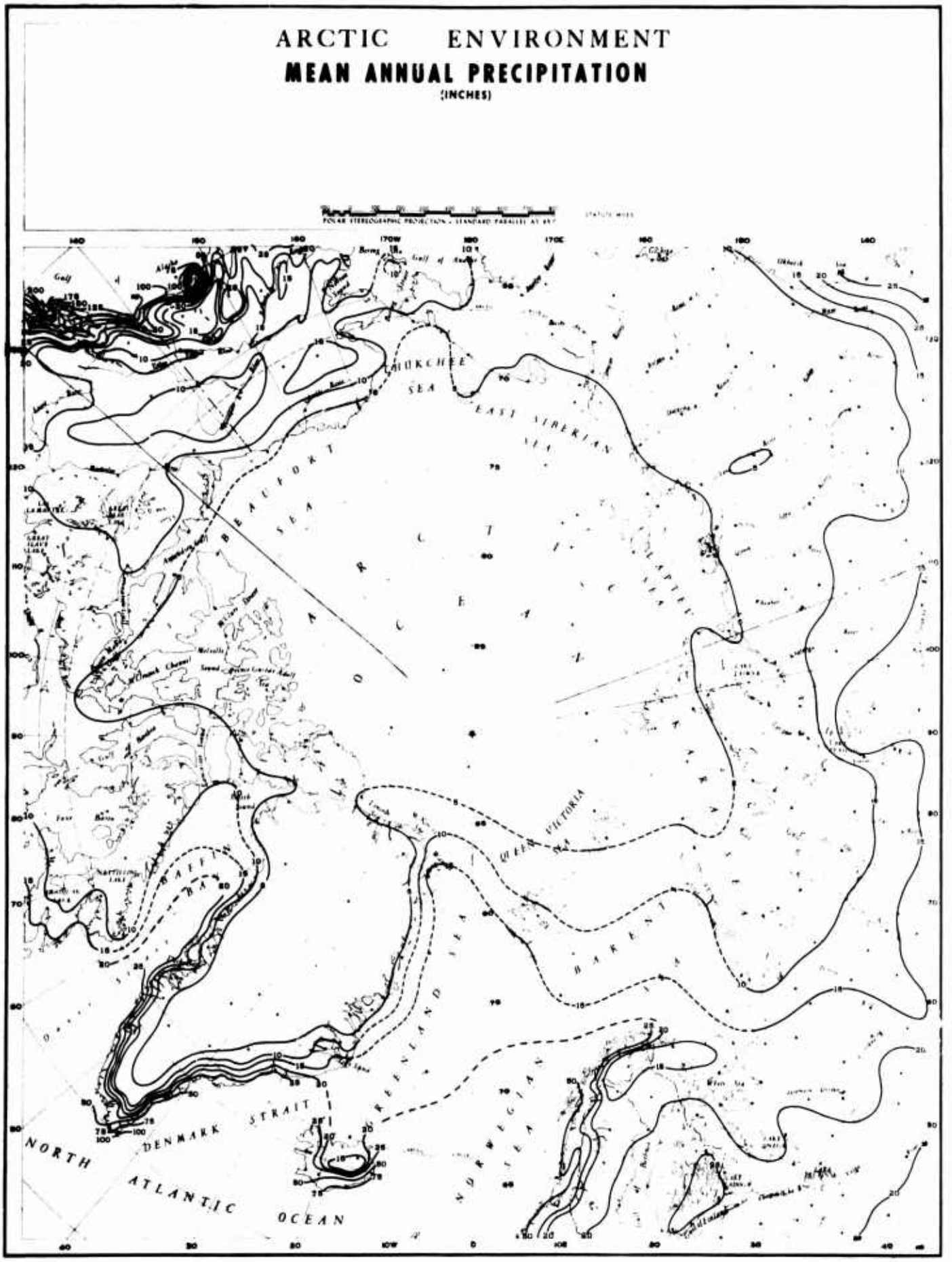
MEAN NUMBER OF DAYS WITH ≥ 0.01 INCH OF PRECIPITATION
AUGUST



ARCTIC ENVIRONMENT

MEAN ANNUAL PRECIPITATION

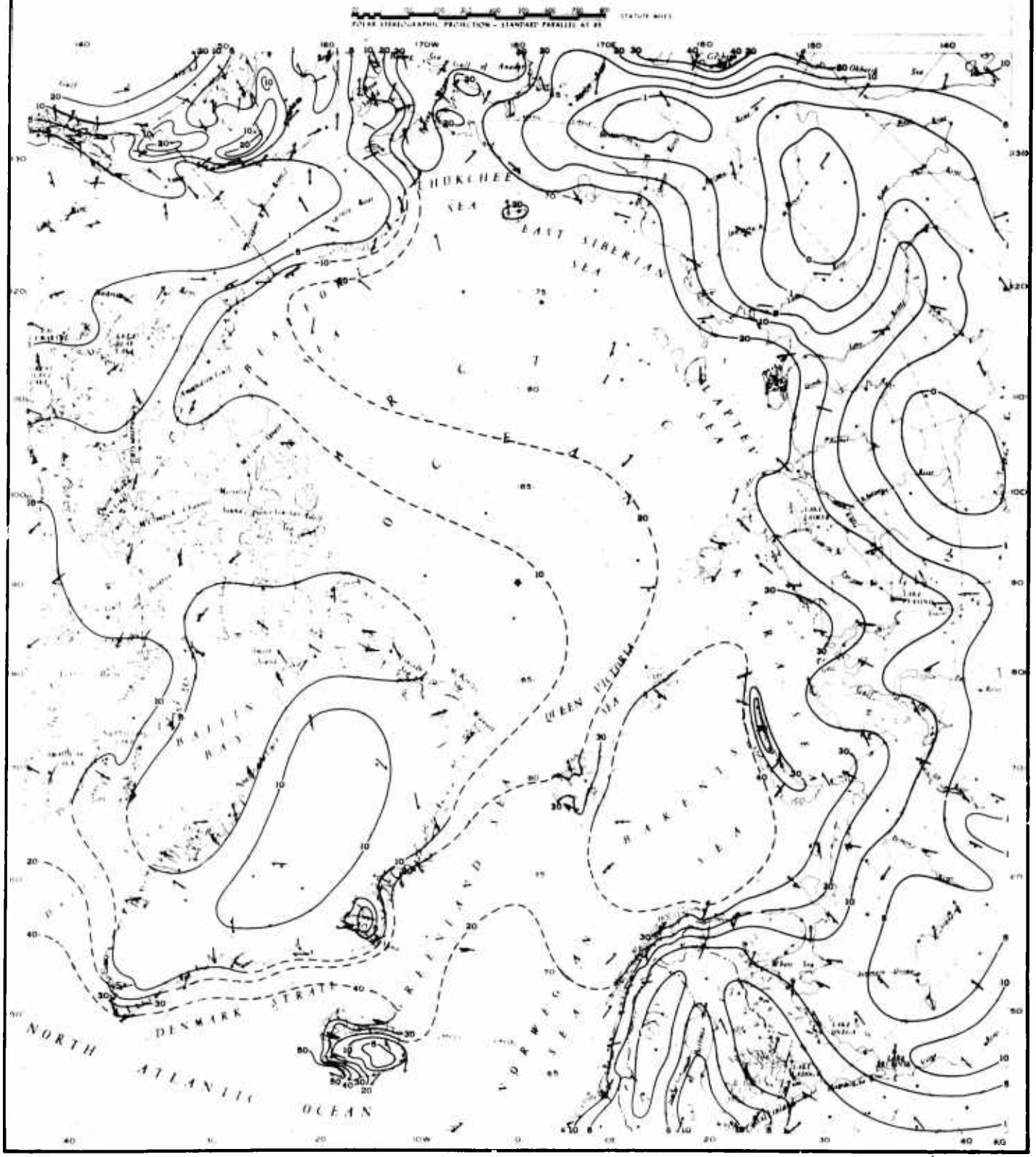
(INCHES)



ARCTIC ENVIRONMENT

MEAN PERCENT OF SURFACE WINDS OVER 24 MILES PER HOUR
DECEMBER-JANUARY-FEBRUARY

Wind arrows fly with the prevailing "ALL - SPEED" direction for the three month period



ARCTIC ENVIRONMENT

MEAN PERCENT OF SURFACE WINDS OVER 24 MILES PER HOUR
JUNE-JULY-AUGUST

Wind arrows fly with the prevailing "ALL - SPEED" direction for the three month period